Flow over a surface with slight roughness is examined. It is established that at high Prandtl or Schmidt numbers such roughness can markedly increase the coefficients of heat and mass exchange.

The hypothesis has been expressed in [1] that the protrusions of irregularities on a surface with relatively slight roughness exert an additional turbulizing effect on the laminar sublayer.

This can be justified physically as follows. Directly at the surface the liquid moves by passing over the elements of roughness. Consequently the particles of liquid will possess additional vibrational motions compared with a smooth surface. These vibrations of the flow increase the level of turbulization and can lead to the appearance of additional shear stresses. It must be noted that the concept itself of a wall boundary in the presence of roughness is somewhat indeterminate if this boundary is measured with respect to the normal to the direction of motion of the external flow. In this case the wall boundary represents an indistinct range of sizes of the protrusions. However, one can arbitrarily take as the wall boundary the coordinate where the longitudinal component of the velocity is equal to zero. In this form it is possible to allow for the presence of the additional turbulization of the flow by a simple shift in the origin of the co-ordinates.

If one adopts for a smooth surface the dependence of [2] corresponding to a fourth power law for the penetration of velocity pulsations into the laminar sublayer, the equation for calculating the velocity profile for a rough surface will have the form

\[
\varphi = \frac{1}{1 + \frac{5.624 [0.0805 (\eta + \eta_r)]^4}{\frac{0.0805 (\eta + \eta_r)^2}{\frac{0.2667}{\eta + \eta_r}}} d\eta.}
\] (1)

At \( \eta_r = 0 \) Eq. (1) corresponds to the uninterrupted flat velocity profile of a smooth surface [2].
The operation of the numerical calculation of the integral (1) is accomplished very simply on an electronic computer by the same program as for a smooth surface, taking the initial values
\[ \eta = \eta_0; \quad q = 0. \]
Then calculating from the profile the average velocity for the motion of a liquid in a round tube
\[ q_r = \frac{2}{\eta_0^3} \int_0^{\eta_0} \eta (\eta_0 - \eta) \, d\eta, \]  
(2)
one can calculate the coefficient of resistance
\[ \zeta = 8/q_r^2, \]  
(3)
corresponding to the Reynolds number
\[ Re_f = 2q_r \eta_0 \]  
(4)and the relative roughness
\[ \frac{y_r}{r_0} = \frac{\eta_r}{\eta_0}. \]  
(5)
Here we use the well-known equations (2)–(5) which follow from calculations in universal coordinates.

As a result of the calculations numerical values were obtained for the coefficients of resistance, which are correlated with an accuracy of ±2% by the dependence
\[ \Psi = \frac{\zeta}{\zeta_s} = 1 \left( 1 - 1.1 \cdot 10^{-2} Re_f^{0.675} \frac{y_r}{r_0} \right). \]  
(6)
The structure of this equation and of the others presented below is obtained by the method of relative correspondence [3] on a simple two-layer model. This method, which has not yet received due appreciation, provides the basis for the application of rougher calculating models in the case when the results of the calculation are represented in relative values. A linear dependence between the displacement \( y_r \) of the origin of coordinates and the height \( \delta \) of the roughness is assumed in [1]
\[ y_r = c\delta. \]  
(7)
By comparison with experiments on the hydraulic resistance in tubes with a sandy surface roughness it is found that \( c = 0.127. \)